



# Managing a Virtual Network Function using SDN and Control Theory

GENI Webinar, October 28<sup>th</sup>, 2016

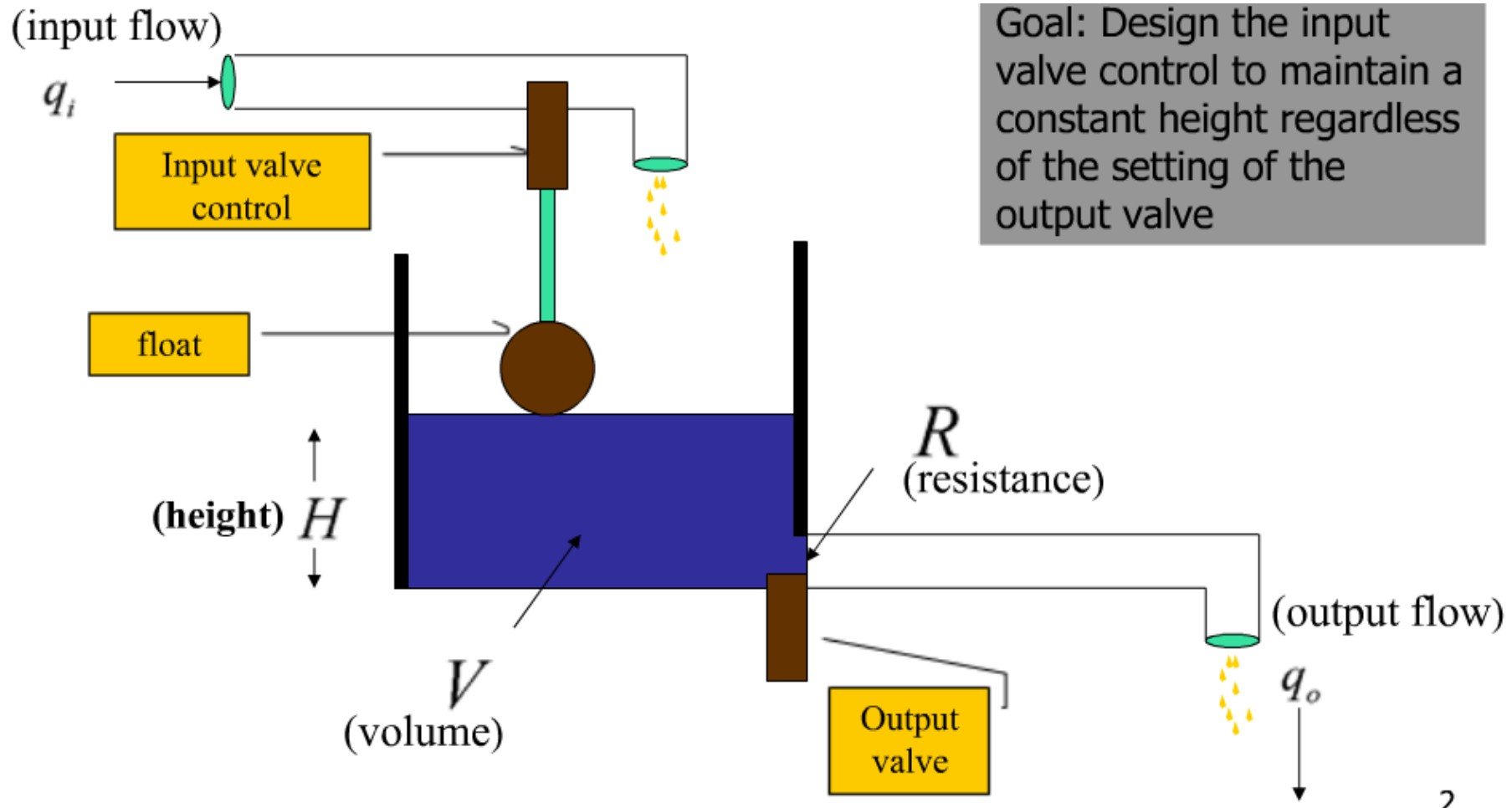
Abraham Matta

Joint work with Nabeel Akhtar and Yuefeng Wang

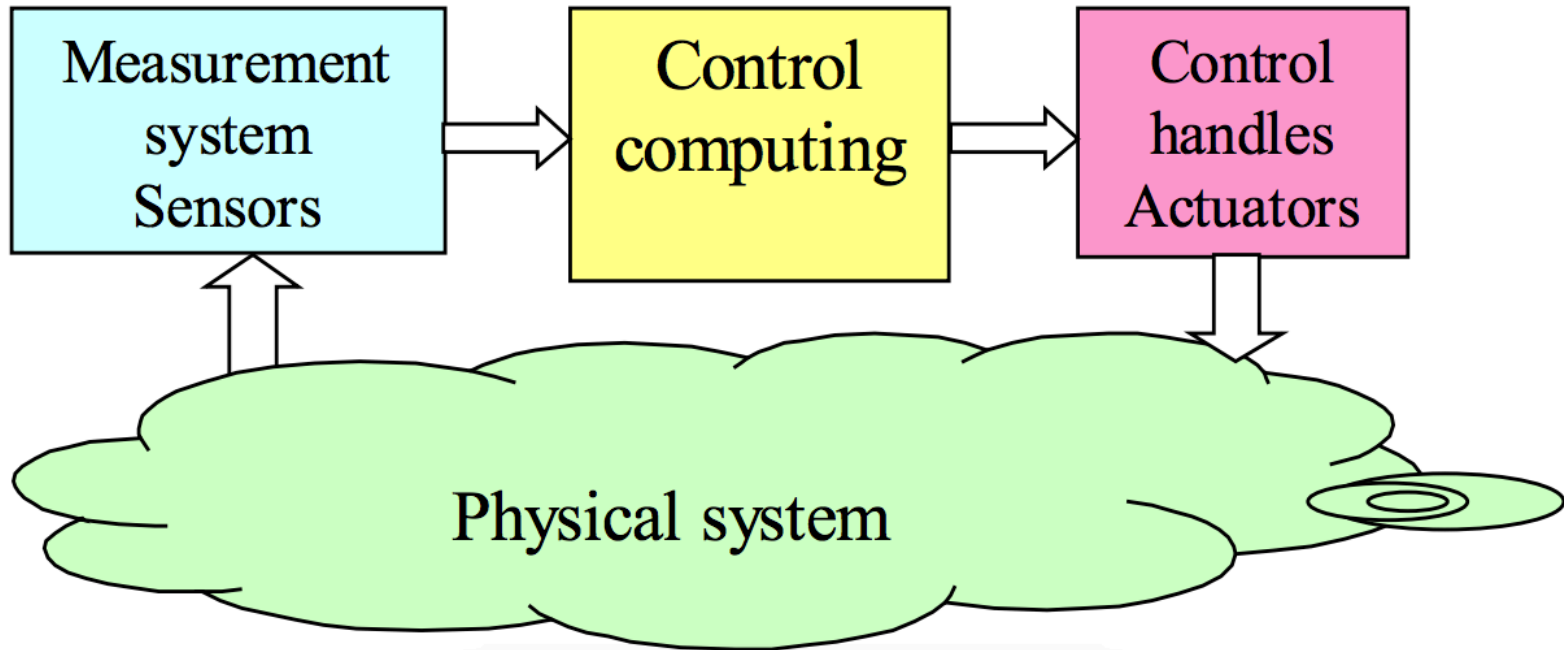
# Control Theory



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**“90% of the real world applications are based on 10% of the existing control methods and theory”**

**Dimitry Gorinevsky – Stanford University**

# Examples of Control Theory in CS

- TCP/IP

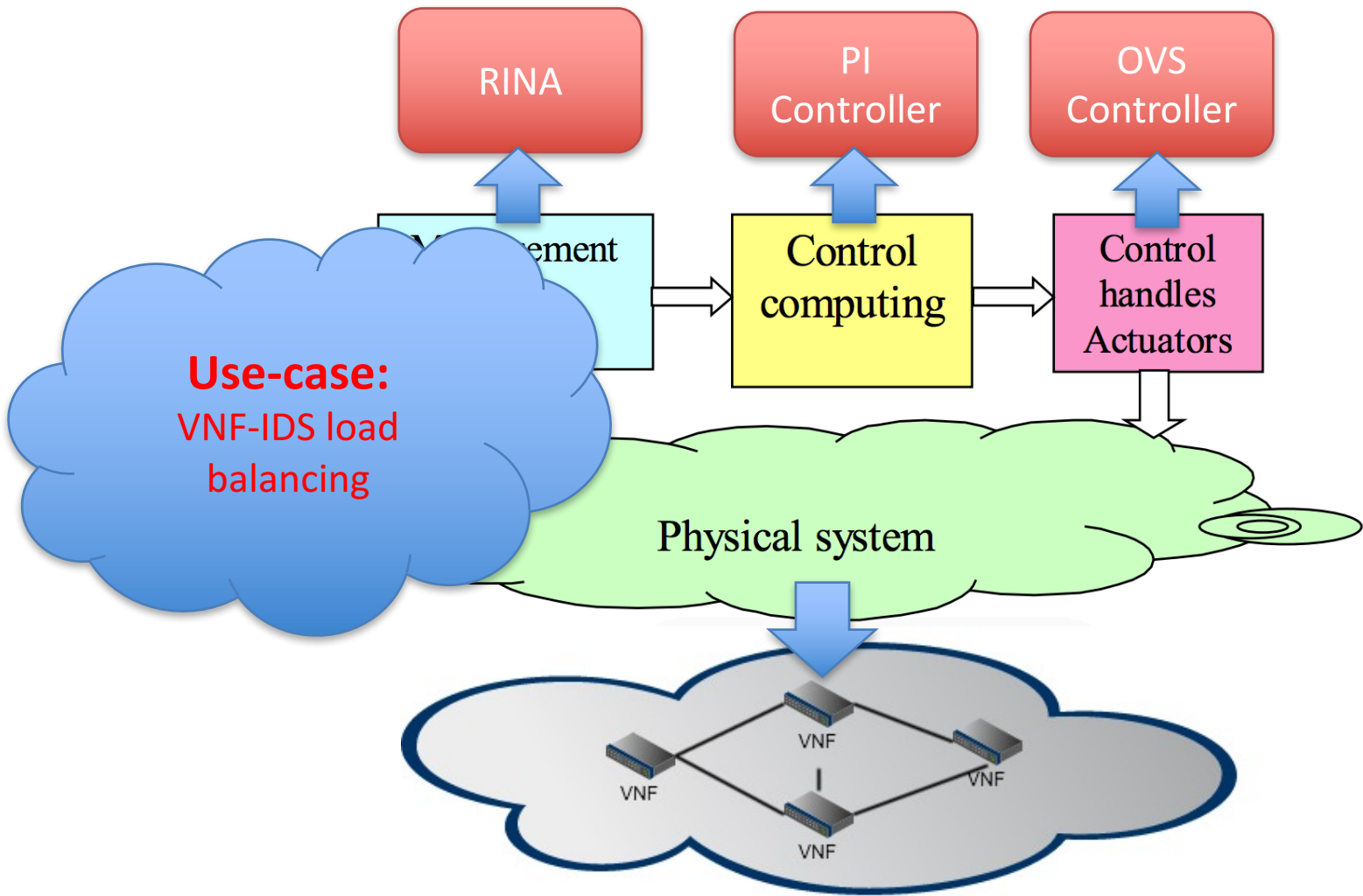
```
for every loss {  
    W = W/2  
}  
for every ACK {  
    W += 1/W  
}
```

$$\dot{x} = \frac{1-q}{\tau^2} - \frac{1}{2}qx^2$$

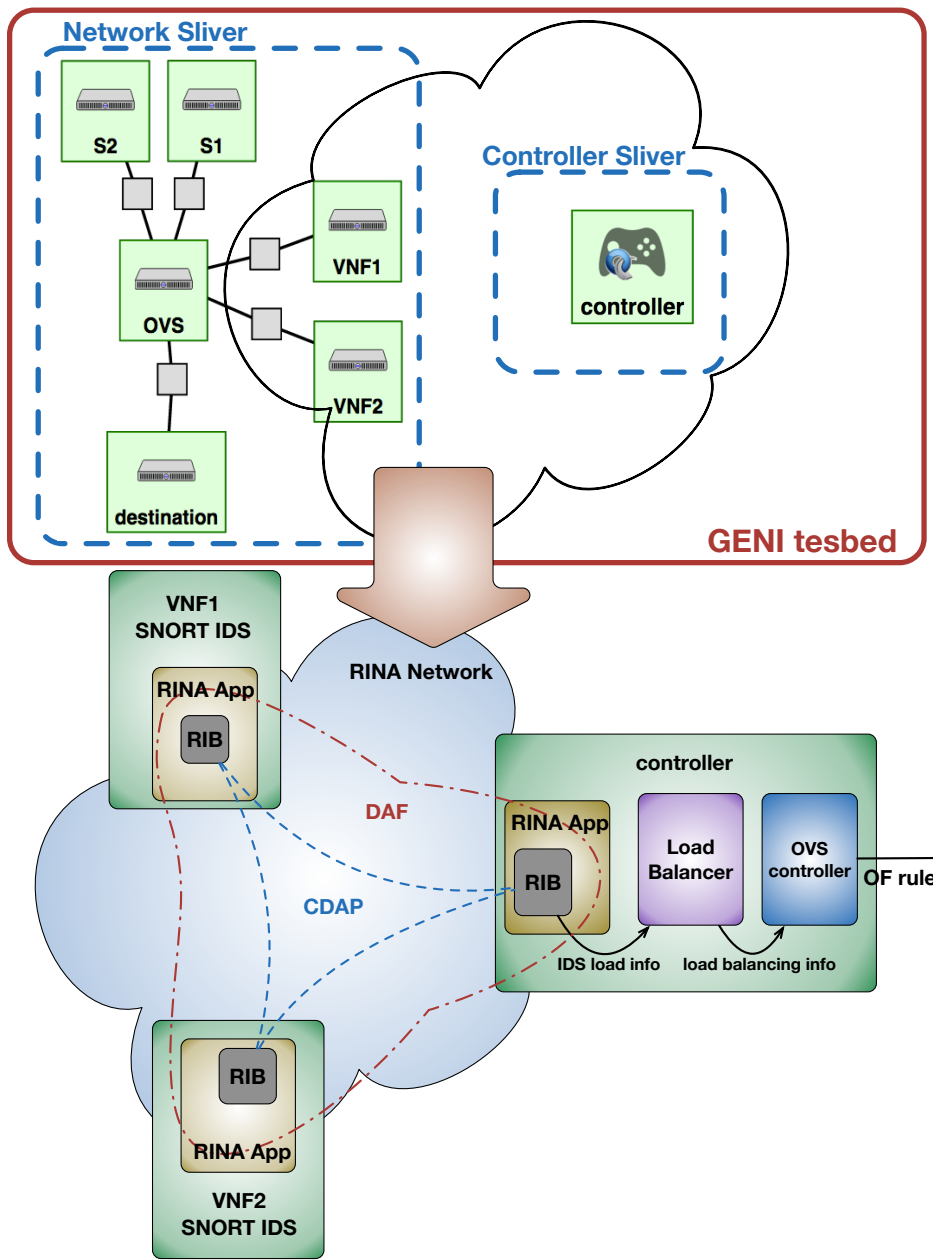
- $x$  - transmission rate
- $\tau$  - round trip time
- $q$  - loss probability

- Analysis and systematic design was developed some 20 years later
- QoS in Caching
- Apache QoS differentiation
- ...
- See: **Optimizing and Modeling Dynamics in Networks**. In Hamed Haddadi and Olivier Bonaventure, editors, eBook on Recent Advances in Networking, volume 1. ACM SIGCOMM, August 2013. Licensed under a [CC-BY-SA](#) Creative Commons license.

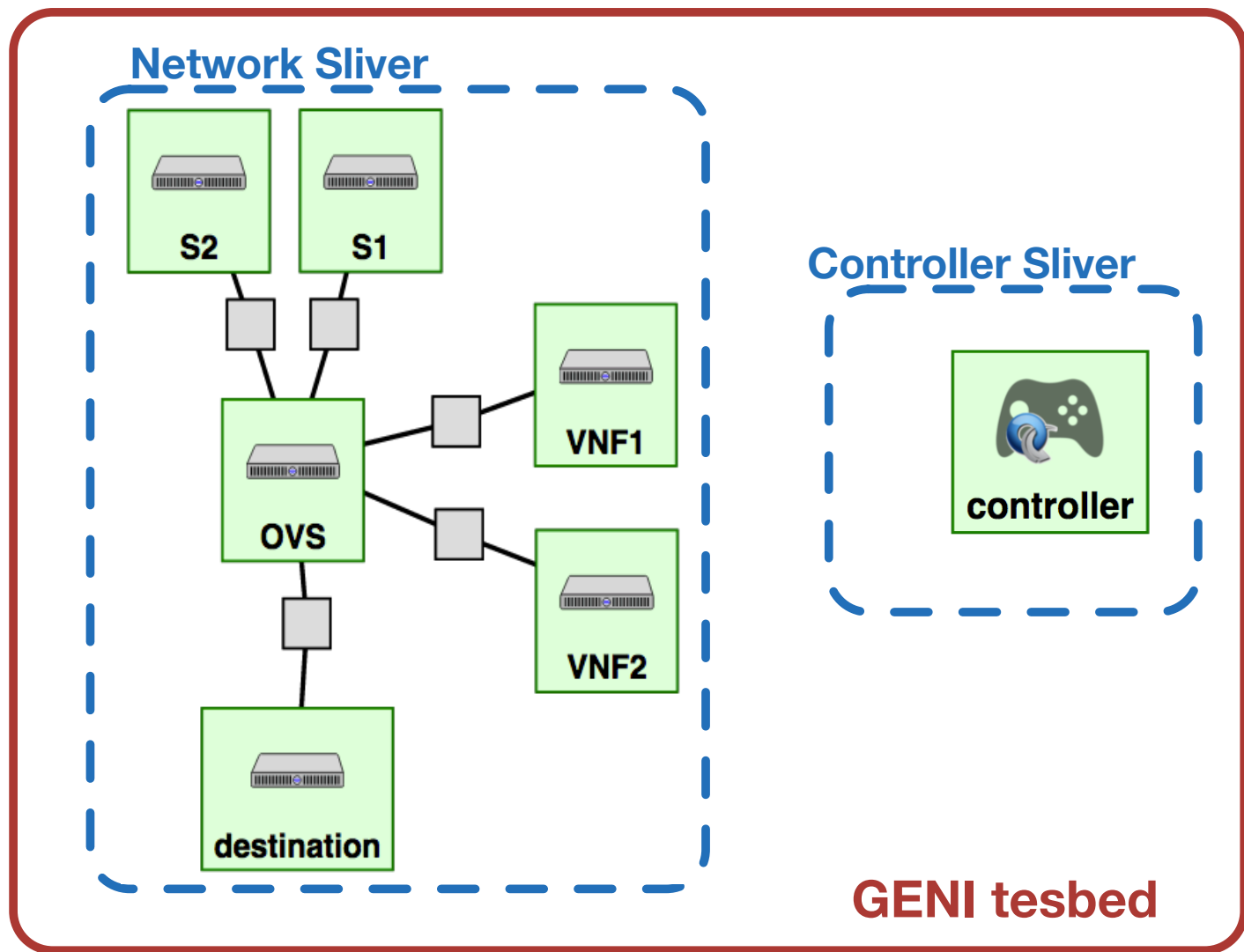
# Managing NFV using SDN & Control Theory



# System Overview



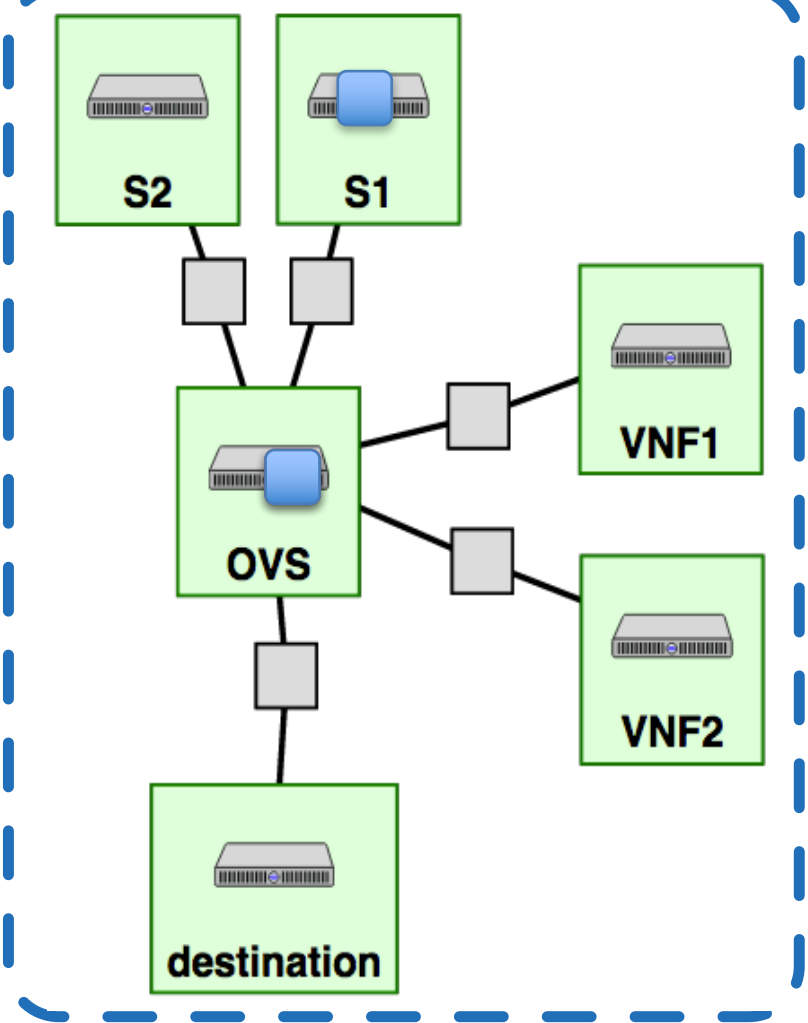
# GENI Test-bed



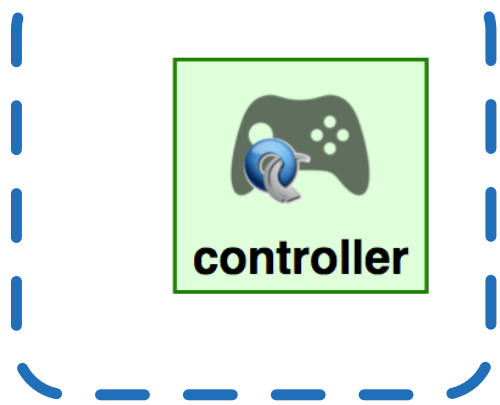


# Network Traffic

## Network Sliver



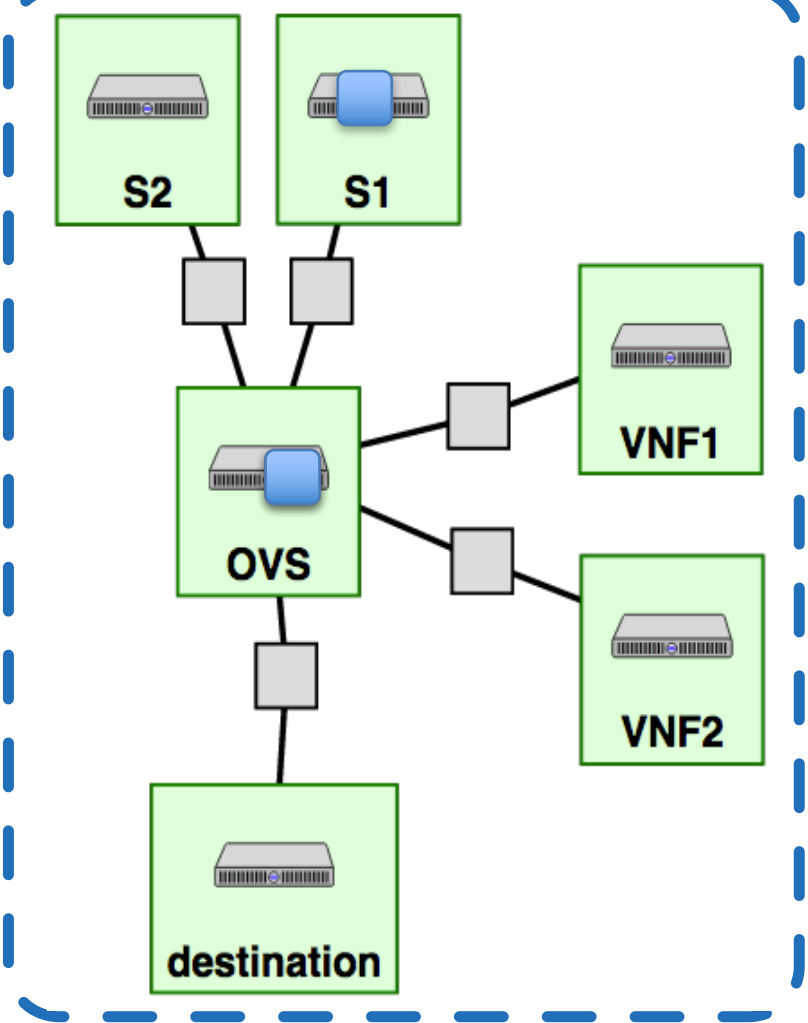
## Controller Sliver



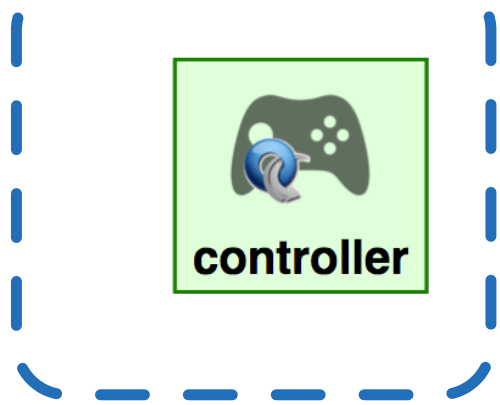
**GENI tesbed**

# Network Traffic

## Network Sliver



## Controller Sliver



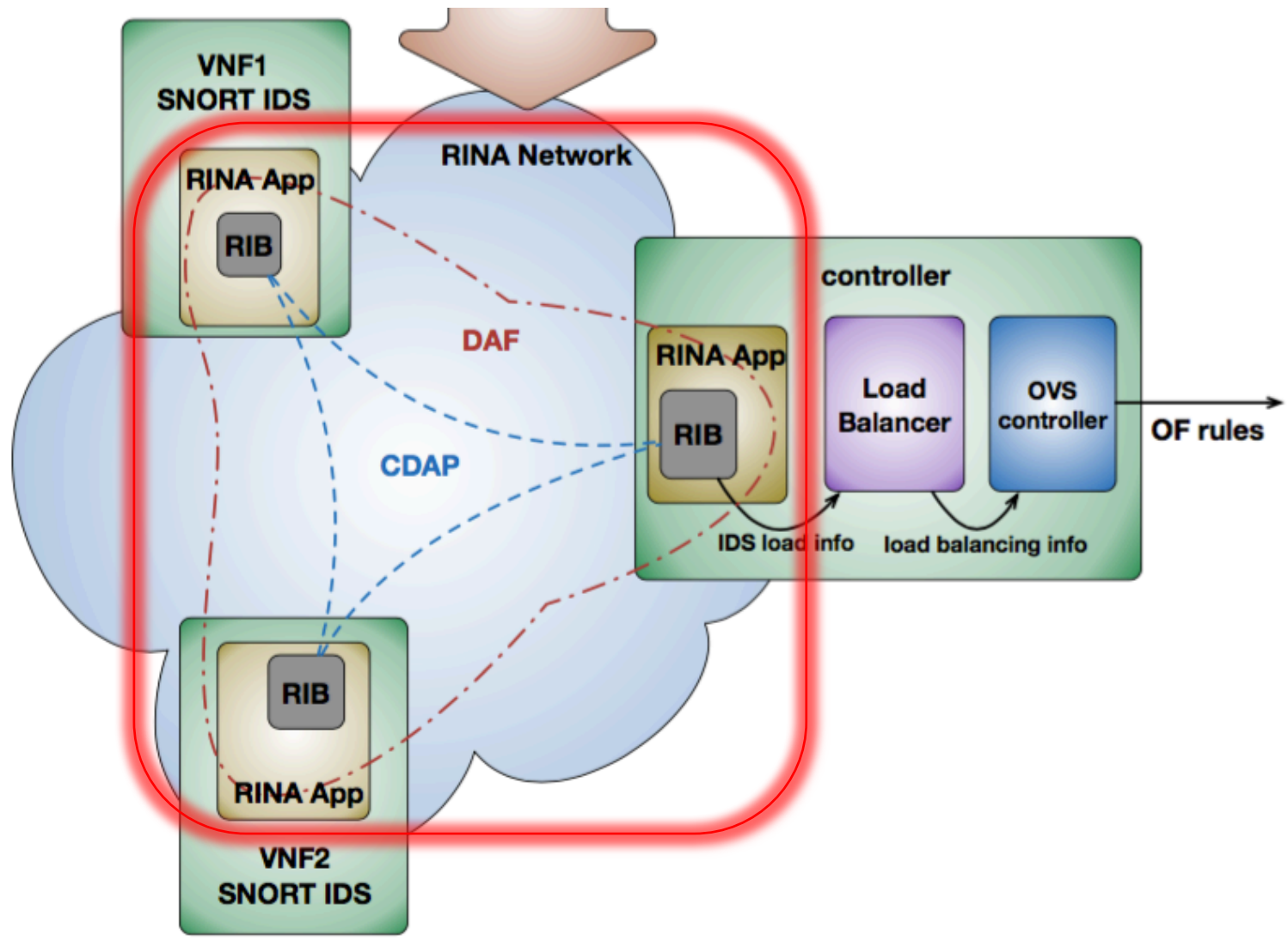
**GENI tesbed**

# Snort as IDS



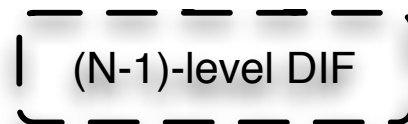
- Open source IDS system widely deployed
- InfoWorld's Open Source Hall of Fame as one of the "greatest open source software of all time"
- Protocol analysis, content searching and content matching

# RINA



# Recursive InterNetwork Architecture (RINA)

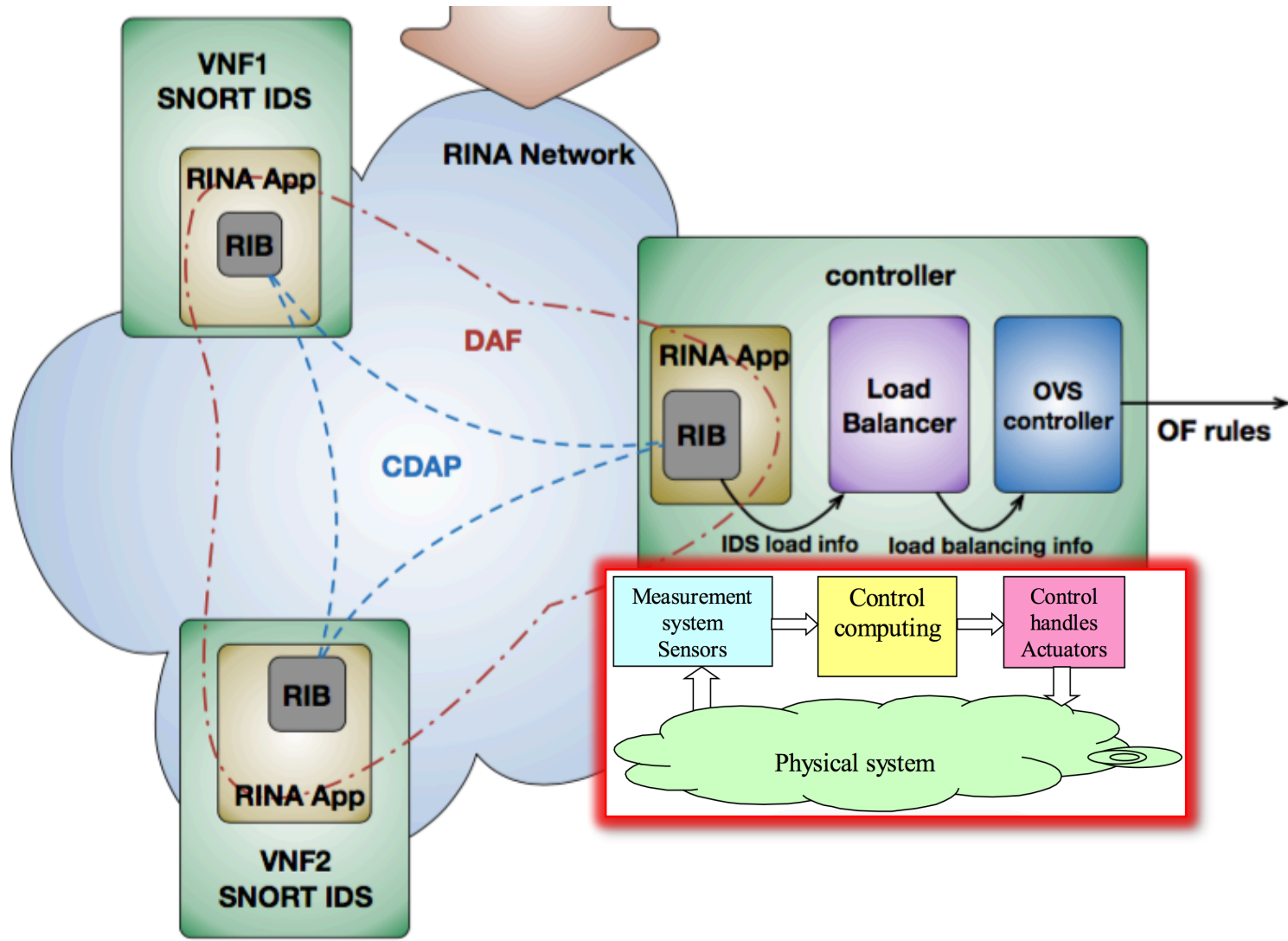
- Clean slate Future Internet Architecture
- Networking is Inter-process communication (IPC)
  - Old principle applied (e.g., TCP RFC 793, 1981)
- DIF (Distributed IPC Facility)
  - processes cooperating to provide IPC
- DAF – processes cooperating to perform a certain function



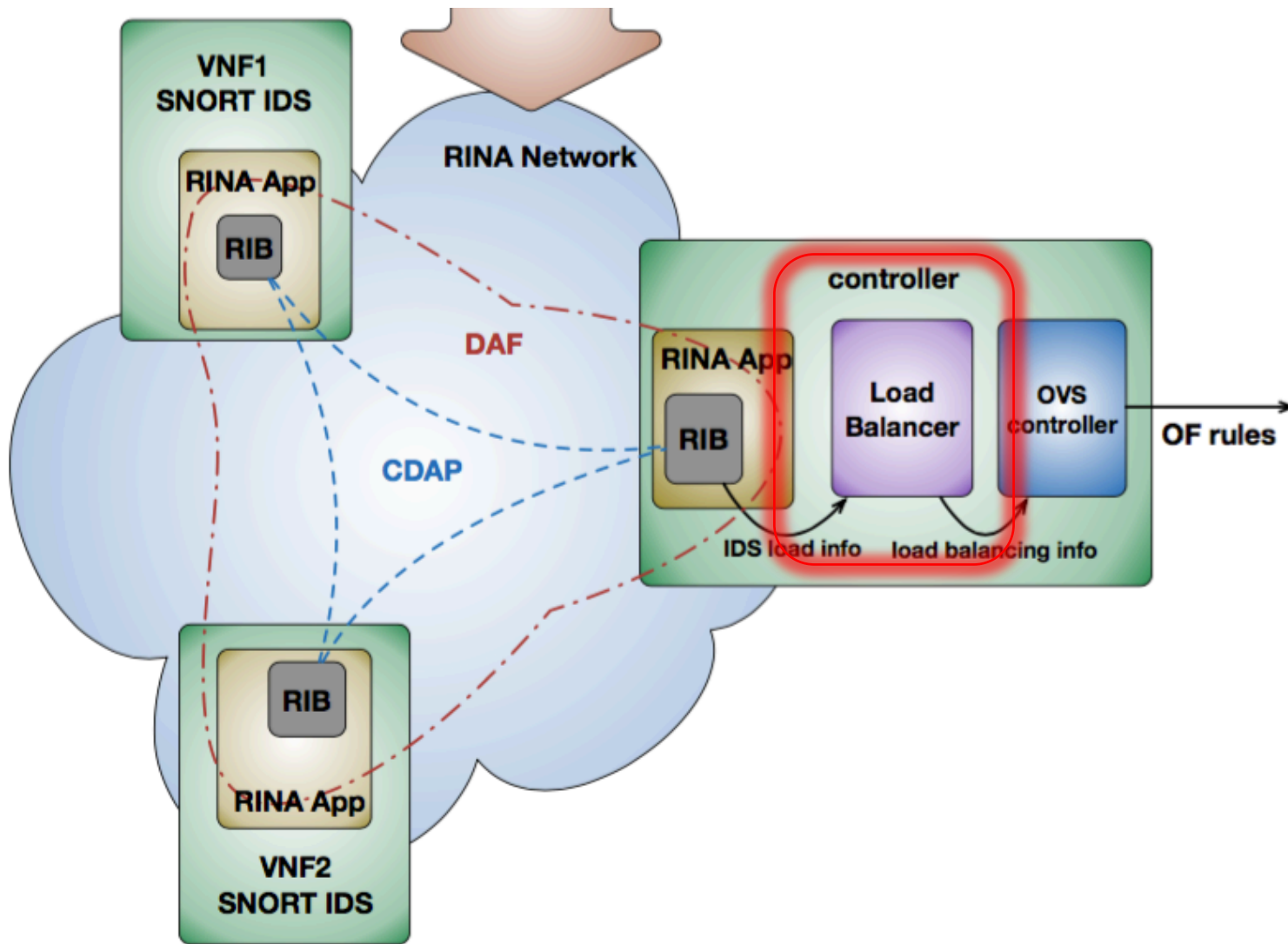
<http://csr.bu.edu/rina/>

See GEC19 Tutorial: [www.youtube.com/watch?v=qUDvduy-JEs](http://www.youtube.com/watch?v=qUDvduy-JEs)

# Controller



# Proportional Integral (PI) Controller



# Proportional Integral (PI) Controller

$$x(t) = \max[0, \min[1, x(t-1) + K(\frac{L(t)}{T} - 1)]]$$

$x(t)$ : ratio of traffic diverted to VNF2 at time  $t$

$L(t)$ : load on VNF1

$T$ : target load on VNF1

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**Algorithm 1** PI controller

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**Input:**  $IDS_{load.txt}$

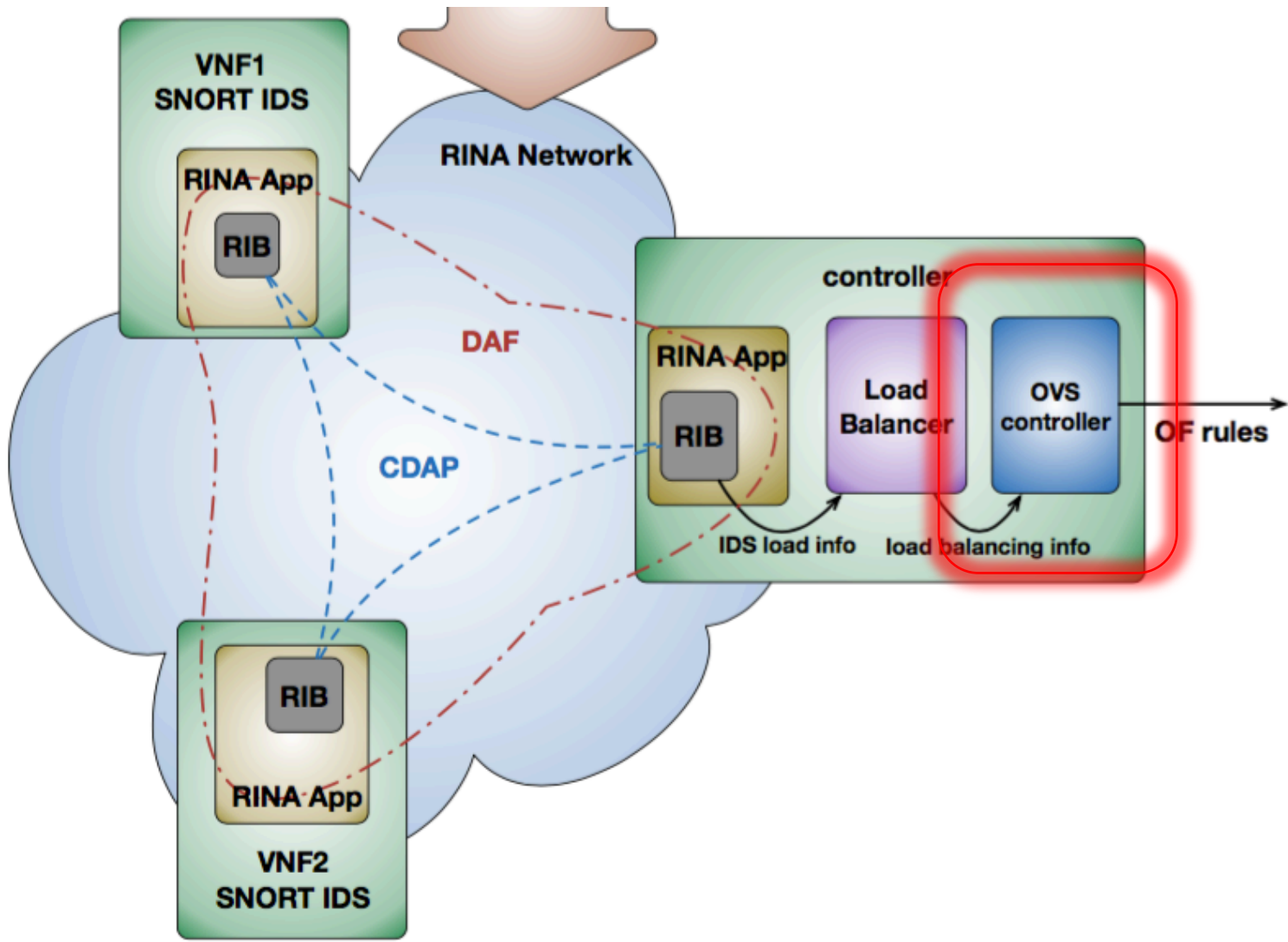
**Output:**  $x(t)$

```
1:  $T = 0.5$ 
2:  $x(t-1) = 0.0$ 
3:  $x(t) = 0.0$ 
4:  $K = 0.2$ 
5: while True do
6:    $L(t) = \text{getLoad}(IDS_{load.txt});$ 
7:    $x(t) = \max[0, \min[1, x(t-1) + K(\frac{L(t)}{T} - 1)]];$ 
8:    $\text{write}(t, x(t));$ 
9: end while
```

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# PI-based OVS Controller



# PI-based OVS Controller

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**Algorithm 2** PI-based OVS controller

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**Input:**  $Flows$ ,  $x(t)$

```
1: for all  $f$  in  $Flows$  do  
2:    $random = generateRandom()$ ;  
3:   if  $random > x(t)$  then  
4:      $vnfSelected = IDS1$ ;  
5:   else  
6:      $vnfSelected = IDS2$ ;  
7:   end if  
8:    $sendFlow(f, vnfSelected)$ ;  
9: end for
```

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# Round Robin based OVS Controller

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## **Algorithm 3** Round Robin based OVS controller

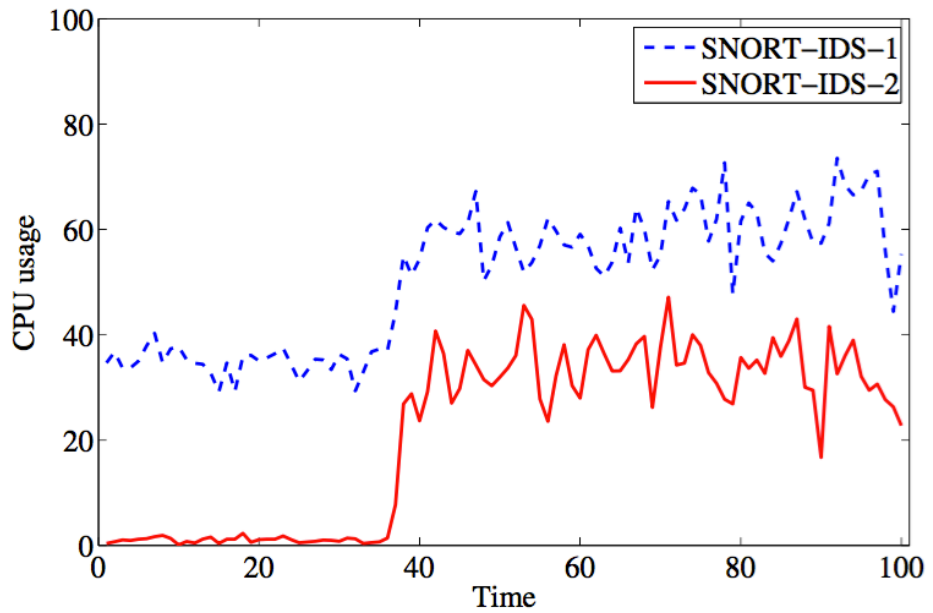
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**Input:** *Flows*

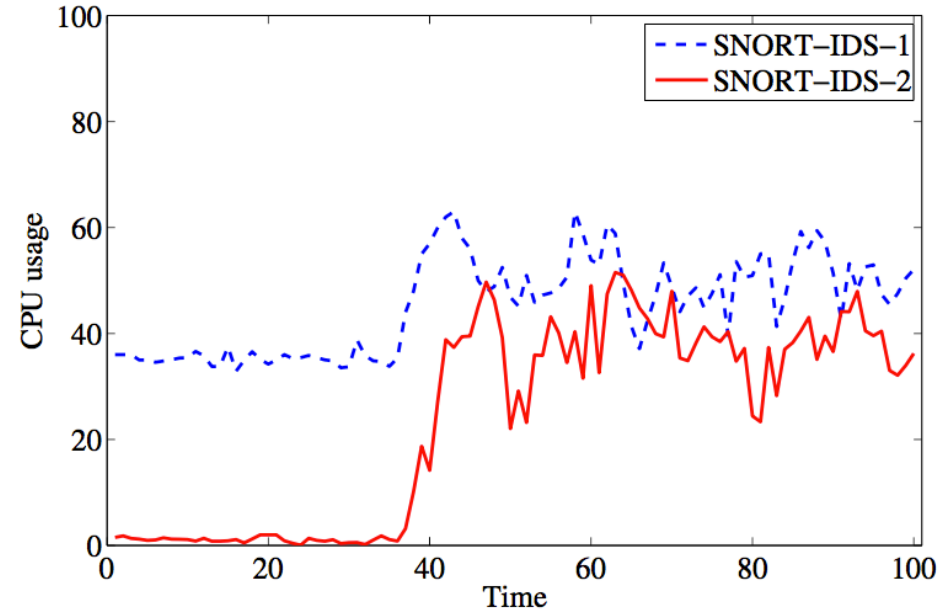
```
1: vnfSelected = IDS1
2: for all f in Flows do
3:   if vnfSelected == IDS1 then
4:     vnfSelected = IDS2;
5:   else
6:     vnfSelected = IDS1;
7:   end if
8:   sendFlow(f, vnfSelected);
9: end for
```

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# Round Robin vs PI Control based load balancer

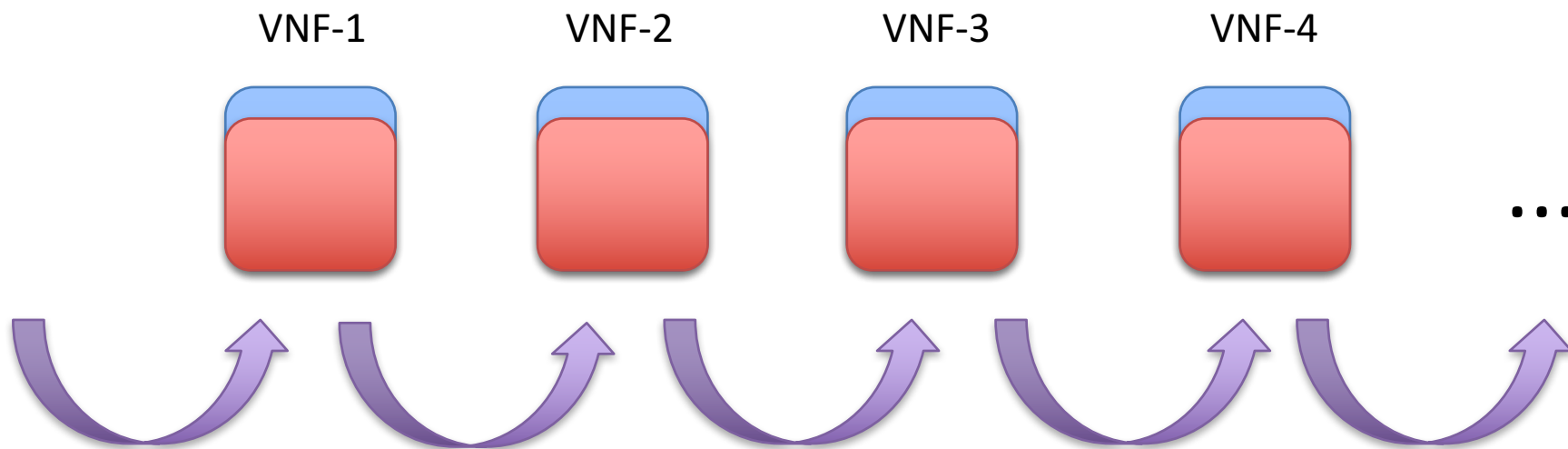


Simple Round Robin load balancing



Load balancing based on PI control ( $T = 50\%$ )

# Scaling



# DEMO

# Conclusion

- First work that combines Control Theory with SDN/NFV management
- Control Theory can play crucial role in SDN/NFV management
- Use case: Load balancer for IDS (VNF)
  - GENI test-bed is used for realistic experimentation
  - RINA based distributed application is used for monitoring
  - PI-Controller
  - Scaling

Tutorial to reproduce results:

POX version:

<http://groups.geni.net/geni/wiki/GENIExperimenter/Tutorials/NFV>

Ryu version:

<http://groups.geni.net/geni/wiki/GENIExperimenter/Tutorials/NFV/Ryu>